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AUTHOR(S): L. R. Avens, L. A. Worl, K. J. deAguero, D. D. Padilla
Nuclear Materials Technology Division

F. C. Prenger, W. F. Stewart, D. D. Hill
Mechanical and Electronic Engineering Division

T. L. Tolt
Lockheed Environmental Systems and Technologies

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MAGNETIC SEPARATION FOR SOIL DECONTAMINATION

Larry R. Avens, Laura A. Worl, Karen J. deAguero, Dennis D. Padilla
Nuclear Materials Technology Division
F. Coyne Prenger, Walter F. Stewart, Dallas D. Hill
Mechanical and Electronic Engineering Division
Los Alamos National Laboratory
and
Thomas L. Tolt
Lockheed Environmental Systems and Technologies

ABSTRACT

High gradient magnetic separation (HGMS) is a physical separation process that is used to extract magnetic particles from mixtures. The technology is used on a large scale in the kaolin clay industry to whiten or brighten kaolin clay and increase its value. Because all uranium and plutonium compounds are slightly magnetic, HGMS can be used to separate these contaminants from non-magnetic soils. A Cooperative Research and Development Agreement (CRADA) was signed in 1992 between Los Alamos National Laboratory (LANL) and Lockheed Environmental Systems and Technologies Company (LESAT) to develop HGMS for soil decontamination. This paper reports progress and describes the HGMS technology.

INTRODUCTION

It is estimated that more than two million cubic meters of soil are contaminated with plutonium, uranium, and fission products in the Department of Energy (DOE) Defense Complex.(1) The Department of Defense has additional contaminated sites. One of the goals of the DOE Office of Environmental Restoration and Waste Management (EM) is to remediate these sites. High gradient magnetic separation (HGMS) is a physical separation process that can selectively extract many radioactive materials from soils. Development of HGMS will result in a more effective and less expensive soil decontamination method.

HIGH GRADIENT MAGNETIC SEPARATION

Magnetic separation is a physical separation process that segregates materials on the basis of magnetic susceptibility. Because the process relies on physical properties rather than chemical properties, separations can be achieved while producing a minimum of secondary waste.

When a paramagnetic (slightly magnetic) particle encounters a non-uniform magnetic field, the particle is urged in the direction in which the field gradient increases. Diamagnetic particles are affected in the opposite sense. When the field gradient is of sufficiently high intensity, paramagnetic particles can be physically captured and separated from extraneous diamagnetic material.

Many fission product elements and all plutonium and uranium compounds are paramagnetic (Table 1).(2) Because most soil components are diamagnetic, magnetic separation of paramagnetic contaminants from soil is feasible. The advent of reliable superconducting magnets producing high fields makes magnetic separation of weakly paramagnetic species possible.

Place table 1 here

While numerous magnetic separation methods exist, (3) HGMS appears to be well suited for soil decontamination. A diagram of the method is shown in Figure 1. Most commonly the feed is slurried with water and passed through a magnetized volume. Field gradients are produced in the magnetized volume by a matrix material. The matrix can be any ferromagnetic material such as steel wool, steel balls, or nickel foam. Under proper conditions, ferromagnetic and paramagnetic particles can be extracted from the slurry while the diamagnetic fraction passes through the magnetized volume. Later, the magnetic fraction is flushed from the matrix when the magnetic field is reduced to zero or the matrix is removed from the magnetized volume.

Place fig. 1. here

In many respects HGMS is a mature technology. The kaolin clay industry in Georgia uses HGMS to remove magnetic colored contaminants from clay slurries.(4) Superconducting magnets are used routinely to process this clay on the thirty ton per hour scale.

Conventional electromagnets are limited by the saturation of iron to magnetic fields of about 2 tesla. Higher fields offered by superconducting magnets make possible a broader range of HGMS applications. For our HGMS work we have a laboratory scale conventional electromagnet and an 8 tesla superconducting magnet. The conventional magnet was recently installed in the Los Alamos plutonium facility. This will allow us to test uranium and plutonium contaminated soil samples. The superconducting magnet is located in an unrestricted area and is used for tests with nonradioactive surrogates.

SOIL DECONTAMINATION

HGMS can have an enormous impact as a unit operation for soil decontamination. The low technology/high cost method of soil remediation is to simply package and ship the large volumes of soil to a repository. However, costs for disposal of uranium and plutonium contaminated soil are approximately \$1200 and \$3500 per cubic meter respectively.(5) These high costs preclude the disposal of large volumes of soil in this manner.

Most soil decontamination technologies are aimed at reducing the volume of soil that must go to a repository. If 90% of the soil volume can be decontaminated and returned to the local environment, then remediation costs can be reduced by almost an order of magnitude. Also, if the soil is not denatured by the decontamination process, revegetation and reuse of the area can occur in a short period of time.

Soil washing and gravimetric separation methods improve on the low technology option by concentrating the contaminants into a fraction of the bulk soil volume.(6) However, these methods become ineffective on soil particles smaller than about 50 microns. In addition, a high percentage of radioactive particles exist in the environment as particles smaller than 50 microns and thus can not be separated by soil washing methods. Because HGMS is most effective on particles smaller than about 50 microns and can extract particles as small as 0.1 micron, HGMS is a good fit technically with other physical separation methods. When used in conjunction with soil washing operations, high efficiency extraction of the particulate contaminants in the small particle size fraction can further reduce the volume of soil that must be sent to a repository. Application of

HGMS will allow decontamination, by physical methods of a previously inaccessible class of soils.

RESULTS

To assure rapid transition of HGMS soil decontamination technology to the private sector we teamed with industry early in the project. A Co-operative Research and Development Agreement, or CRADA, was signed with AWC/Lockheed (now LESAT) early in 1992. A Lockheed scientist is working with us full time at Los Alamos.

The CRADA work statement includes three test series, two of which are complete. The first test series consisted of separation experiments on non-radioactive surrogates in water. The second series includes extraneous solids such as silica and clay to make simulated soil slurrys. The third series of tests will be performed on radioactive soil samples that we prepare and samples from actual contaminated sites.

The test series include the examination of: 1) surrogate materials with different magnetic susceptibilities, 2) surrogate particle sizes, 3) flow rate effects, 4) effects of solids loading in the slurry, 5) fluid viscosity effects 5) magnetic matrix parameters, 6) magnetic field orientation, and 7) magnetic field strength. The data from the tests are being used to develop a performance based HGMS model. Soon, given a separation problem, we will have the ability to select a processing protocol that will achieve optimum performance. Currently, numerous experiments must be conducted to determine optimum performance. Data from the tests series and analytical model are also being used by LESAT to design a prototype separator.(6)

At a remediation site certain properties, such as the particle size and magnetic susceptibility of the contaminant particles, are not in our control. The analytical model gives us the ability to predict performance under the less than ideal conditions encountered in the field.

HGMS performance has been exceptional in test series one and two. In one test we extracted a non-radioactive surrogate (with a magnetic susceptibility less than that of plutonium oxide) to levels below our detection limit of 13 parts per billion. We feel that three orders of magnitude (99.9%) decontamination of particulates from soils can be easily achieved. Six orders of magnitude decontamination may be possible.

From the tests we have learned that the key performance variables for the application of HGMS to soil decontamination are: soil dispersion, particle size, solids loading in the slurry, and particular properties of the magnetic matrix material. Tests are still being conducted to determine the optimum magnetic matrix material and configuration.

An example of the data generated by a test is shown in Figure 2. The figure shows the extraction performance of a copper oxide magnetic surrogate as a function of both the number of passes through the magnetic field and the solids loading in the slurry. The solid was submicron size illite-beidellite clay. With a solids content of 30%, only about half of the magnetic surrogate was extracted. Performance increases dramatically as the solids content was reduced to the 5% to 10% range. The data point for the second pass of 20% solids test is an estimated value as the result of an analysis problem. We should add that these tests were conducted to obtain relative extraction data for the analytical model. Under optimum extraction conditions removal of copper oxide from the slurry to much lower levels is possible.

Place fig. 2 here

One potential problem identified early in the experimental program, could be a high content of magnetic components in the soil. A high content of magnetic components in the soil could preclude removal of magnetic contaminants. To address this problem a series of HGMS tests were conducted on the fine particle size fraction of soils from various DOE sites. Table 2 shows the results of that study. Of the particle size fraction smaller than 45 microns, less than six percent of the soil was captured by the magnetic separator. Also, no flow restriction or excessive pressure drop was detected in these experiments. We concluded that this amount of magnetic soil components would not lead to HGMS processing difficulties.

Place Table 2 here

CONCLUSION:

The HGMS test series one and two of the CRADA have been completed. Sufficient data has been obtained to complete the analytical model. Separation performance in the surrogate studies exceeded our expectations. The LESAT HGMS prototype design is complete as described in the companion paper at this conference.(6) Major remaining tasks include radioactive sample testing and data correlation with the analytical model. This work should be completed in the summer of 1993. We anticipate deployment and demonstration of the LESAT prototype separator late in 1993.

REFERENCES

1. P. M. Arnold, et al., "Site Survey Report: Transuranics in Soil at DOE Facilities," RFP-3107, Rockwell International, (Nov. 1980).

2. D. R. Lide, Handbook of Chemistry and Physics, 71st ed., pp. 9-14-9-18, Chemical Rubber Company, McGraw Hill, New York.,(1990)

3. J. Oberteuffer, "Magnetic Separation: A review of Principals, Devices, and Applications," IEEE Trans. on Magnetics, Vol. 10, No. 2, pp. 223-238, (1974).

4. J. Iannicelli, "Development of High Extraction Magnetic Filtrationby the Kaolin Industry of Georgia," IEEE Trans. on Magnetics, Vol. 12, No. 5, pp. 489-503, (1976).

5. T. Wenstrand, Personal Communication, LESAT, (1992).

6. H. E. Plumblee, et al., "Enhancement of TRUclean System Performance with an Actinide Magnetic Separation System," Proceedings of Waste Management 93, Tucson, AZ. (1993).

TABLE 1

Volume Magnetic Susceptibility of Selected Compounds and Elements

Compound or Element	Susceptibility X 10^6 (SI)
FeO	7178
Fe_2O_3	1479
Ce	1463
UO_2	1204
Cr_2O_3	844
Pd	805
NiO	740
Am	707
Pu	636
U	411
PuO_2	384
CuO	242
RuO_2	107
UO_3	41
MoO_3	26
Al	21
CaO	-1
ThO_2	-7
ZrO_2	-8
MgO	-11
KCl	-13
$CaCl_2$	-13
SiO_2	-14
Graphite	-14
Al_2O_3	-18

TABLE II

Magnetic Properties of Selected Soil Samples

Soil Sample	Soil Fraction[a] <45 micron (%)	Magnetic Fraction <45 micron (%)
Fernald[b]	66.1	4.9
INEL[c]	63.9	5.2
Los Alamos	26.2	3.4
Oak Ridge	53.2	5.5
Rocky Flats	47.8	5.8
SRS[d]	21.8	5.0

(a) <45 micron fraction obtained by sieving soil samples dried at 90 degrees Celsius.

(b) All magnetic fractions collected at 2 tesla except the Fernald sample which was collected at 0.5 tesla.

(c) Idaho National Engineering Laboratory

(d) Savannah River Site

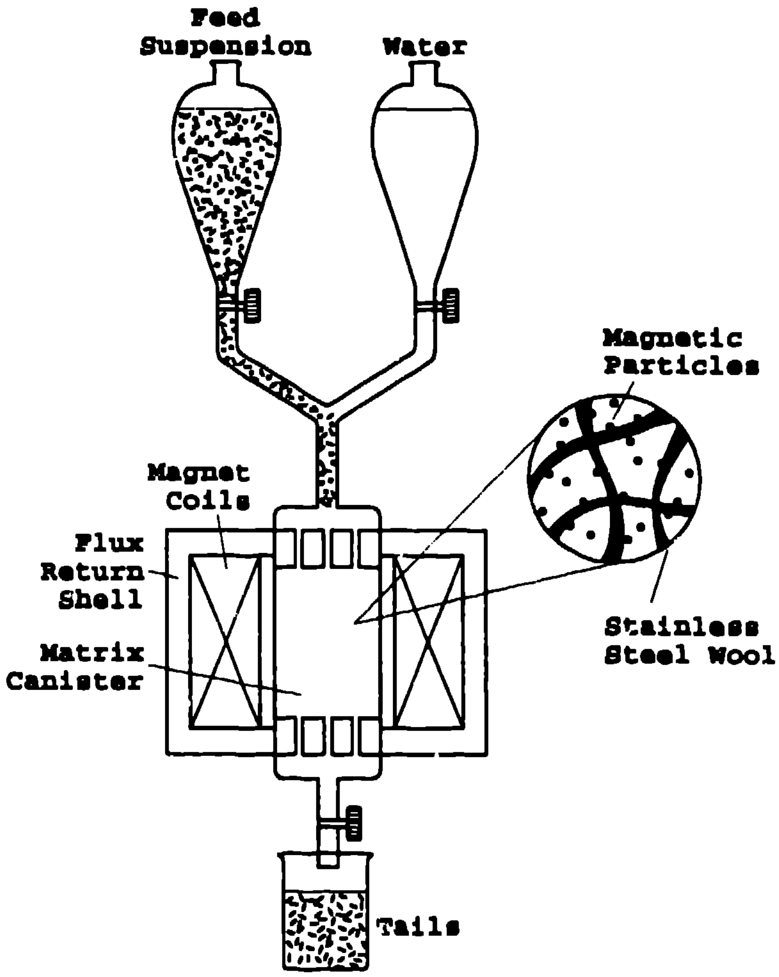

Fig 1. Simplified HGMS Diagram

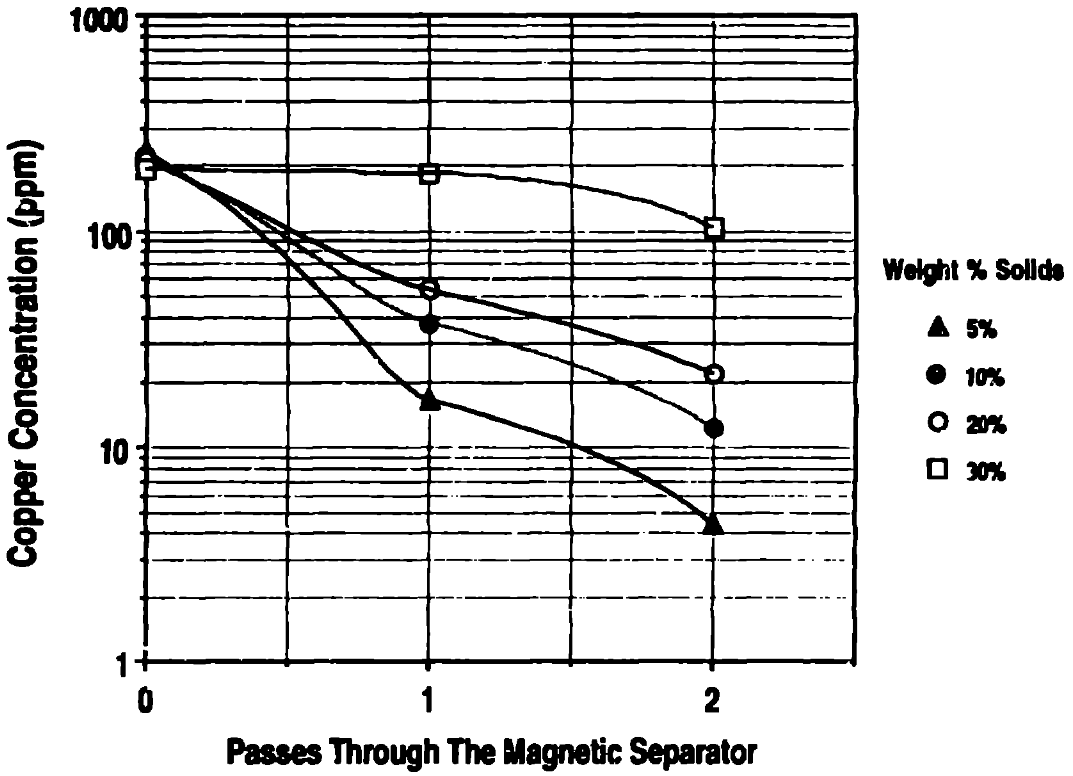

Fig 2. HGMS Test Results For a Copper Oxide/Illite-Beidellite Slurry With Various Levels of Solids Content.